

Spectral Mass-Gauging of Unsettled Liquid With Acoustic Waves

Completed Technology Project (2015 - 2016)



Project Introduction

The ability to quickly and accurately gauge the amount of available propellant in a tank is one of the basic requirements of propellant management.

1. Under settled or partially settled conditions, various mass-gauging techniques are under development. However, these techniques require installation of hardware inside the tank which is undesirable.
2. In microgravity (unsettled) conditions, both the location and shape of the ullage are *a priori* unknown. Presently, there are no technological solutions capable of determining the volume of unsettled liquid propellant for arbitrary ullage shapes in a tank¹ to within a few per cent accuracy as required for deep space NASA missions.²⁻³

The proposed approach aims to overcome the two major limitations of the present technologies: (1) the need of installation of hardware inside the tank; (2) assumption of particular ullage shape. In addition, the approach is (3) applicable to both conducting (MMH) and non-conducting liquids (LOx, LH2) (in contrast to RFMG approach); (4) based on different physical principles from the existing approaches, therefore enabling the required redundancy in mass-gauging in those cases (settled or partially settled liquids), where alternative approaches are satisfactory.

Overall Concept: Spectral Mass-gauging (SMG) – computes propellant volume using the acoustic resonances counting function in the propellant tank; it is based on rigorous results from spectral theory (Weyl's Law), providing a shape-invariant spectral characteristics⁴. Weyl's law provides a rigorous tool to infer the volume of the liquid in partially filled tanks: (i) for arbitrary shapes of the ullage, (ii) systematically controlling accuracy, limited only by the acoustic dissipation, which is found to be very low in space applications and allows reaching theoretical limit of fractions of percent of the tank volume. While Weyl's law is well-known in mathematical community and has been tested in fundamental research⁵, it has never been applied to acoustic mass-gauging of liquids in space applications, where it offers big promise due to the large dimensions of the tanks; nature of the fluid (liquid) and character of the boundary conditions (vacuum).

Anticipated Benefits

Liquid mass gauging in both unsettled and settled conditions for NASA long duration spaceflight missions: the proposed solution will eliminate the need to perform a settling burn to measure the remaining propellant mass; in future space infrastructures, such as propellant depot, ISRU units etc. for mass gauging under all conditions.



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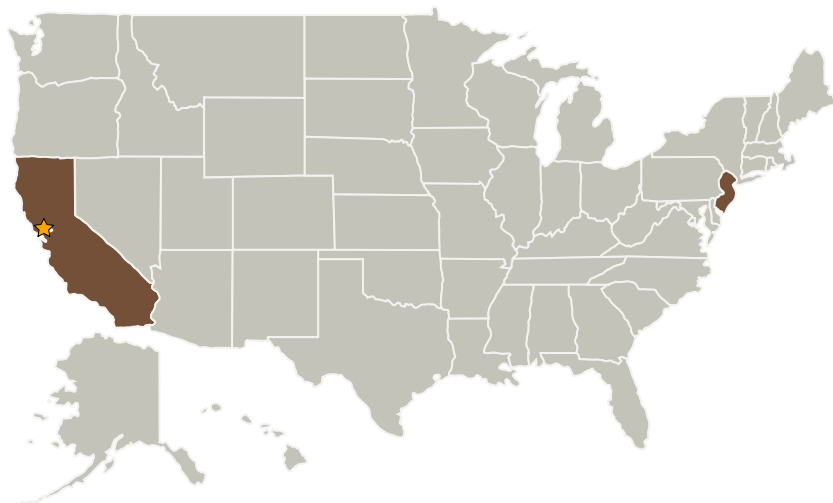
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Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★ Ames Research Center(ARC)	Lead Organization	NASA Center	Moffett Field, California
New Jersey Institute of Technology(NJIT)	Supporting Organization	Academia	Newark, New Jersey

Primary U.S. Work Locations

California	New Jersey
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Stories

Spectral Mass-Gauging of Unsettled Liquid with Acoustic Waves
<https://techport.nasa.gov/file/35201>

Project Website:

<https://www.nasa.gov/directorates/spacetech/home/index.html>

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Center / Facility:

Ames Research Center (ARC)

Responsible Program:

Center Innovation Fund: ARC CIF

Project Management

Program Director:

Michael R Lapointe

Program Manager:

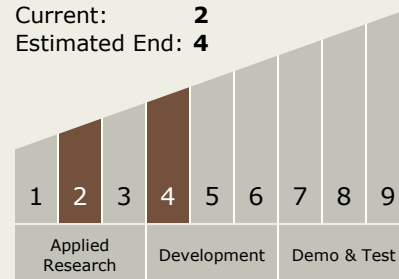
Harry Partridge

Principal Investigator:

Andre G Petukhov

Technology Maturity (TRL)

Start: 2
 Current: 2
 Estimated End: 4



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Technology Areas

Primary:

- TX14 Thermal Management Systems
 - └ TX14.1 Cryogenic Systems
 - └ TX14.1.1 In-space Propellant Storage & Utilization